X-ray unit for the generation of brief X-ray pulses and inspection device operating with such an X-ray unit

Description

The invention relates to an X-ray unit for the generation of brief X-ray pulses. The X-ray unit contains an X-ray tube with a thermionic cathode and an anode and also an X-ray generator with a first circuit for the generation of a high-voltage pulse which can be applied to the anode to generate the X-ray pulse.

The invention also relates to a device for inspecting containers, e.g. drinks bottles or suitcases or travelling bags, which are conveyed on a transport apparatus. The inspection device has an imaging apparatus with an X-ray unit of the type named at the outset.

X-ray units for the generation of brief X-ray pulses are known from DE-C-32 16 733, US-A 4 947 415 and WO 94/23552. These units serve to generate extremely brief X-ray pulses lasting a few nanoseconds. Specially developed capacitors are used to generate the high-voltage pulse, in order to be able to transmit the high-voltage energy to the anode within the extremely brief pulse duration.

An X-ray unit with an electron field emission cathode is known from WO 02/31857, with which X-ray pulses of different energies can be generated by focussing the electron beam on different anode materials.

An X-ray beam generator for the generation of X-ray pulses is known from EP-A-1 158 842, the high voltage being applied permanently to the anode and the grid voltage being controlled according to the cathode current such that during the period

in which no X-ray beams are to be generated, no electrodes reach the anode. The pulse duration is also controlled by means of the grid voltage. It is thereby to be made possible to generate a stable X-ray pulse.

It is known to use X-rays to inspect drinks bottles and luggage which are moved past an imaging apparatus onto a transport device. X-ray image intensifiers or converters with a downstream CCD camera are used as imaging systems and the recorded image relayed to an evaluation system. By using a surface sensor in the X-ray image intensifier it is possible to greatly reduce both the radiation energy and also the power input of the X-ray pulse. Due to the movement of the X-rayed objects, the contours of the images lack sharpness, however.

If other sensors are used, e.g. line sensors, the whole of the energy must be made available continuously, i.e. even when no test object is in the beam path. Firstly, high radiation energies are released, and secondly, high electric outputs are required, as a result. Expensive screening and security measures are therefore required for radiation protection and high connected loads of the equipment.

The object forming the basis of the invention is to create an X-ray unit which makes it possible to generate X-ray pulses in the millisecond range and makes possible contour-sharp images with relatively low radiation energy.

According to the invention this object is achieved in an X-ray unit of the type named at the outset in that the X-ray generator has a second circuit via which permanently low voltage is applied to the anode.

By "low voltage" is meant here a high voltage at which at the most low-energy X-radiation is generated which is already absorbed by the glass wall of the X-ray tube. Because this low voltage is permanently applied to the anode, practically no X-radiation is generated, but the X-ray tube is pre-heated so

that the X-ray tube can be quickly powered-up at any time and a brief X-ray pulse generated.

The X-ray tube operates in simmer mode. The second circuit is a simmer power supply unit. A protective diode protects the simmer power supply unit when the high voltage is switched on. Another possibility for the generation of the high-voltage pulse is the use of a Marx generator.

The cathode is always heated with constant heating current via a heating control.

Such an X-ray unit is suitable in particular for devices for the inspection of objects, in particular containers which are transported through the inspection device at irregular intervals, as the start phase for powering-up the X-ray tube is extremely brief and essentially is defined only by the discharge curve of the capacitors. In imaging processes in which surface sensors such as X-ray image intensifiers or converters are used it is particularly advantageous that movement blurs are avoided.

In imaging processes which operate with line sensors, e.g. a plurality of photomultiplier tubes arranged in a row with the scintillator crystals, it is advantageous that the high beam power need not be permanently available, i.e. even if no object to be inspected is in the beam path.

The X-ray unit according to the invention is suitable in particular as an X-ray beam source in the case of the [...] in the utility model application DE-U-202 17 559.6 (application date: 12th November 2002, title: "Device for testing filled containers using X-rays").

An embodiment of the invention is described below with the help of the drawings. There are shown in:

Fig. 1 a circuit diagram of the X-ray unit;

Fig. 2 a circuit diagram of a Marx generator and

Fig. 3 a device for the inspection of drinks bottles in which the X-ray unit represented in Fig. 1 is used.

According to the circuit diagram of Fig. 1 the cathode 12 of an X-ray tube 10 is connected to a heating control 14. This provides the cathode 12 with a constant heating current. Anode 16 is connected via a high-voltage switch 18 to a high-voltage capacitor 20 which is charged by a high-voltage power supply unit 22. Anode 16 is also connected to a simmer power supply unit 26 via a protective diode 24.

The high-voltage power supply unit 22 charges the high-voltage capacitor 20 to 60 kV. By closing the high-voltage switch 18 this voltage is applied to anode 16 of X-ray tube 10, whereby an X-ray 30 is generated.

The X-ray tube 10 is operated in simmer mode by a simmer power supply unit 26, the simmer power supply unit 26 producing a voltage of approximately 5kV and permanently allowing a direct current of between approx. 1 and 10 mA to flow through the X-ray tube 10. The X-ray tube 10 is thereby pre-heated to the point where it immediately powers up and generates an X-ray 30 as soon as the high-voltage switch 18 is closed. The simmer power supply unit 26 is protected against the high voltage of the capacitor 20 by the protective diode 24.

Instead of the high-voltage power supply 22 and the high-voltage capacitor 20 and the high-voltage switch 18 a Marx generator can be used as shown in Figure 2. The Marx generator is a voltage multiplier with which a pulsed high voltage can be generated. A number of n capacitors 33 which are connected parallel via resistors 34 is charged via a voltage source 32. To trigger the high-voltage pulse, the capacitors 33 are

connected in series via an electronic switch 36. Then the n-fold capacitor voltage is applied to the output 38.

If e.g. a voltage source 32 of 5 kV and 12 parallel-connected capacitors 33 are used, the generated high-voltage pulse is 60 kV. Therefore, in the present case the simmer power supply unit 26 can be used as voltage source 32.

Fig. 3 shows a device for the inspection of drinks bottles 40 which are conveyed on a transport apparatus 42, e.g. a link chain conveyor. On one side of the transport apparatus 42 there is an X-ray tube 10 and on the opposite side of the transport apparatus 42 an X-ray image converter 44 behind which a CCD camera 46 is arranged. A trigger signal is generated by means of an apparatus such as a light barrier or a capacitive sensor if a drinks bottle 40 to be inspected is located between the X-ray tube 10 and the X-ray image converter 44. The high-voltage switch 18 is closed by the trigger signal, so that the X-ray tube 10 generates a pulse-like X-ray 30. After passing through the bottles 40 the X-ray 30 strikes the X-ray image converter 44 and generates there an image of the drinks bottle 40. The image is recorded by the CCD camera 46 and processed in known manner by image-recognition processes in order to recognize foreign bodies, e.g. glass splinters, in the filled drinks bottle 40. In order that any glass splinters are not masked by the bulge at the bottom of the drinks bottle 40 the X-ray tube 10 is arranged above the plane of the transport apparatus 42 and directs the X-ray 30 at an angle of e.g. 30° from above onto the container bottom, as is described in detail in the above-named utility model application DE-U-202 17 559.6 (title: "Device for testing filled containers using X-rays").

Reference numbers

10 X-ray tube
12 Cathode
14 Heating control
16 Anode
18 High-voltage switch
20 High-voltage capacitor
22 High-voltage power supply unit
24 Protective diode
26 Simmer power supply unit
30 X-radiation
40 Drinks bottle
32 Voltage source
33 Capacitors
34 Resistors
36 Switch
38 Output
42 Transport apparatus
44 X-ray image converter
46 CCD camera